2.10 Instrumented Methods

2.10.1 Ram Penetrometer

Objectives

The ram penetrometer is used to obtain a quantifiable measure of the relative hardness or resistance of the snow layers. It can be applied on its own as an index of snow strength, but it is not recommended as the sole tool for determining snow stability. When used in combination with a snow profile, a ram profile should be taken about 0.5 m from the pit wall after observation of the snow profile, but before any shovel shear tests are performed. It is a valuable tool for tracking changes in relative hardness over time at study plots and slopes, or for measuring many hardness profiles over an area without digging pits.

> *Note: The ram profile describes the hardness of layers in the snowpack. However, it often fails to identify thin weak layers in the snowpack. Surface hoar layers or other weak layers that are one centimeter or less are difficult to detect. Its sensitivity is dependent on the hammer weight, particularly when used in soft or very soft snow. The magnitude of this problem may be reduced by using a lightweight hammer (500 g or less), or by using a powder or "Alta" ram (Perla, 1969).*

Refer to Chapter 6 of *The Avalanche Handbook* (McClung and Schaerer, 1993) for a complete discussion on ram profiles.

Equipment

The standard ram penetrometer, also called ramsonde, consists of:

a) 1 m lead section tube with 40 mm diameter cone and an apex angle of 60°,
b) guide rod and anvil,
c) hammer of mass 2 kg, 1 kg, 0.5 kg, 0.2 kg or 0.1 kg,
d) one or two (1.0 m each) extension tubes.

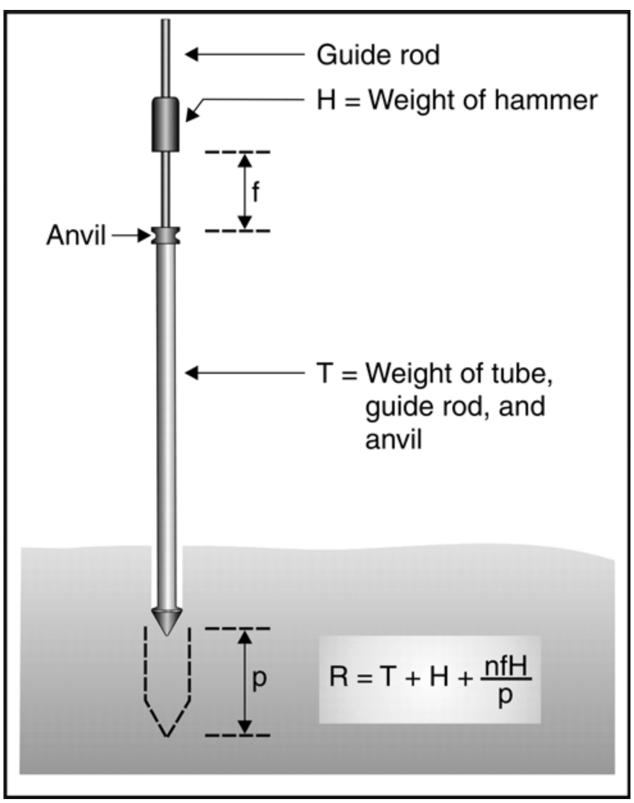

Figure 2.21 Schematic of the ram penetrometer (after Perla and Martinelli, 1976).

The powder ram, also called an Alta Ram (Perla, 1969), consists of:

a) 0.50 m to 1.0 m lead section and guide rod and anvil weighing 100 g,
b) q hammer of mass 0.1 kg,
c) lead section cone has the same dimensions as a standard ram.

The mass of hammer chosen depends on the expected hardness of the snow and desired sensitivity. Observers typically use 0.5 to 1.0 kg hammers.

Unit of Measure

A ram profile depicts the force required to penetrate the snow with a ram penetrometer. The mass of the tubes, the mass of the hammer, and the dynamic load of the falling hammer all contribute to the applied force. Ram profiles can display two different quantities: *ram number* (*RN*), which is a mass (kg), and *ram resistance* (*RR*), which is a force (N).

Weight is a gravity force that is calculated by multiplying mass with the acceleration due to gravity (g = 9.81 m/s^2). Although not strictly correct, most practitioners multiply by 10 to simplify the calculations. Since the ram number is an index of hardness, there is little danger in rounding this value. Force, and consequently the ram resistance, are measured in newtons. A mass of 1 kg has a gravity force (weight) of 1 kg x acceleration, which is approximately 10 N (1kg x 10 m/s^2 =10N).

Procedure

Record the location, date, time, observers, slope angle, aspect, and ram type at the head of the data sheet. Also record any notes that will be pertinent to data analysis after leaving the field.

Work in pairs if possible. One person holds the ram penetrometer in a vertical (plumb) position with the guide rod attached. This person drops the hammer, counts the number of blows, and observes the depth of penetration. The other person records the information. The person holding the ram and dropping the hammer calls three numbers to the recorder: the drop number, drop height and penetration. For example, “6 from 30 is 148”, means 6 drops from a drop height of 30 cm penetrated to 148 cm (Figure 2.22).

a) Hold the first sectional tube with the guide rod attached directly above the snow surface with the point touching the snow. Let the instrument drop and penetrate the snow under its own weight without slowing it down with your hand. You will need to guide it in many cases so it does not fall over. Record its mass in column *T* + *H*. Read the penetration (cm) and record in column *p* (see Figure 2.22 for field data sheet example). Note that many people carry out this first step without attaching the guide rod first. However, since the tube weight *T* is 1.0 kg with the guide rod, it should be attached before the surface measurement is taken. Sometimes a greater sensitivity of the surface layer is desired. Dropping only the lead section without the guide rod will reduce the weight and may cause less of an initial plunge through the surface layers since the total mass will be lighter. If this method is used, then the weight of the lead section alone should be recorded for the *T* value, not the combined lead section and guide rod value of 1.0 kg.
b) Carefully add the hammer, or guide rod and hammer if using the lead section only for the surface measurement. Record the mass of the tube + hammer under *T* + *H*. Read the new penetration and record under *p*. If the ram does not penetrate further, as is often the case in this step, record the previous *p* value again.
c) Drop the hammer from a height between 1 cm and 5 cm; record the penetration. The low drop height (1-5 cm) is appropriate for near-surface layers. Larger drop heights (20-60 cm) and increased hammer weights may be desired as depth, and therefore, resistance increases. Continue dropping the hammer from the same height until the rate of penetration changes. Record fall height *f*, number of blows *n*, and penetration *p* up to the point. Some experience will allow the user to anticipate changes in the structure of the snow and record measurements before the rate of penetration changes. Continue with another series of blows; choose a fall height that produces a penetration of about 1 cm per blow. Do not change fall

height or hammer weight within a series of measurements. Record the series then adjust fall height or change hammer weight if desired before beginning another series. Resolution of the profile depends on the frequency of recorded measurements and the snowpack structure. Many recorded measurements in a homogeneous layer will provide no more resolution than fewer measurements since the calculated *RN* will be the same for both. However, resolution will be lost in varied layers if too many drops are made between recordings as the layer will receive a single *RN* over the entire range of *p* for that layer.

c) Add another section of tube when necessary and record the new *T* + *H*.
d) Repeat the measurements (b and c) until the ground surface is reached.

RAM DATA SHEET				
Location: Glory Bowl, Teton Pass, Wilson, WY				
Date: 19930312	Time: 0750 MST			
Observer: Newcomb/Elder				
Total depth: 239 cm	Equipment: Standard Ram			
Slope: 28°		Aspect E 80°		
Notes: 30 m south of GAZEX 1 Snowing 3cm/hr - wind SW 10m/s				
Tube and hammer wt *T* + *H* (kg)	Number of falls *n*	Fall height *f* (cm)	Location of point *L* (cm)	Comments
1 + 0	0	0	23	tube & guide rod only, new snow deposited last 18 hr
1 + 0.5	0	0	25	add 0.5 kg hammer - no drop
	6	1	32	
1 + 1	0	0	32	change to 1 kg hammer
	4	5	37	
	11	10	49	
	7	20	52	crust
	5	10	64	
	15	10	87	
2 + 1	0	0	87	add 2nd tube section
	10	20	108	
	13	30	141	
	6	30	148	
3 + 1	0	0	148	add 3rd tube section
	25	30	181	
	22	30	209	
	1	30	215	
	3	10	239	

Figure 2.22 Sample field book page for ram profiles.

Calculation

a) Calculate the increment of penetration *p* for each series of blows by subtracting the previous *p* value from the present *p* value (Figure 2.23).

b) Calculate ram number (*RN*) or ram resistance (*RR*) with the following equations:

$$RN = T + H + \frac{nfH}{p}$$

$$RR = RN \times g$$

where:

- RN = ram number (kg)
- RR = ram resistance (N)
- n = number of blows of the hammer
- f = fall height of the hammer (cm)
- p = increment of penetration for *n* blows (cm)
- T = mass of tubes including guide rod (kg)
- H = mass of hammer (kg)
- g = acceleration due to gravity (m/s^2) = 9.81 m/s^2 ≈ 10 m/s^2

c) Plot on graph paper the ram number or resistance vs. depth of snow (see Figure 2.24).

RAM CALCULATION SHEET								
Location: Glory Bowl, Teton Pass, Wilson, WY								
Date: 19930312	Time: 0750 MST							
Observers: Newcomb/Elder								
Total depth: 239 cm		Equipment: Standard Ram						
Slope: 28^o		Aspect: E 80^o						
Notes: 30 m south of GAZEX 1 Snowing 3cm/hr - wind SW 10m/s					*RN = T + H + (nfH)/p* (kg) *RR = RN x 10* (N)			
Tube and hammer wt *T* + *H* (kg)	Number of falls *n*	Fall height *f* (cm)	Location of point *L* (cm)	Penetration *p* (cm)	*(nfH)/p* (kg)	*RN* (kg)	*RR* (N)	Height above ground (cm)
								239
1 + 0	0	0	23	23	0.0	1.0	10	216
1 + 0.5	0	0	25	2	0.0	1.5	15	214
	6	1	32	7	0.4	1.9	19	207
1 + 1	0	0	32	0				207
	4	5	37	5	4.0	6.0	60	202
	11	10	49	12	9.2	11.2	112	190
	7	20	52	3	46.7	48.7	487	187
	5	10	64	12	4.2	6.2	62	175
	15	10	87	23	6.5	8.5	85	152
2 + 1	0	0	87	0				152
	10	20	108	21	9.5	12.5	125	131
	13	30	141	33	11.8	14.8	148	98
	6	30	148	7	25.7	28.7	287	91
3 + 1	0	0	148	0				91
	25	30	181	33	22.7	26.7	267	58
	22	30	209	28	23.6	27.6	276	30
	1	30	215	6	5.0	9.0	90	24
	3	10	239	24	1.3	5.3	53	0

Figure 2.23 Sample work sheet page for calculating ram profiles.

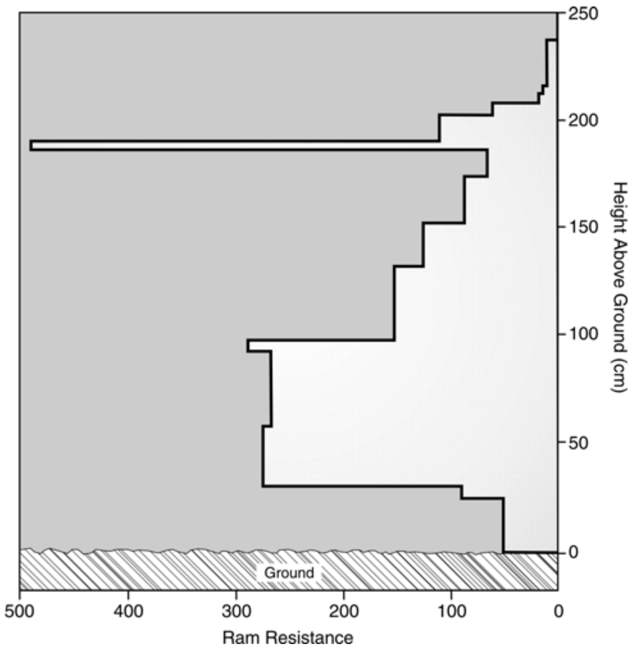

Figure 2.24 Graphical representation of a ram profile from data listed in Figures 2.22 and 2.23.